

CHAPTER 5c

Hand-Arm Vibration Syndrome

SUMMARY

In general, the studies listed in Table 5c-1 show strong evidence of a positive association between high level exposure to hand-arm vibration (HAV) and vascular symptoms of hand-arm vibration syndrome (HAVS). These studies are of workers with high levels of exposures such as forestry workers, stone drillers, stone cutters or carvers, shipyard workers, or platers. These workers were typically exposed to hand-arm vibration acceleration levels of 5 to 36 m/s². These studies typically were cross sectional studies which examined the relationship between workers with high levels of exposures to hand-arm vibration with a non-exposed control group. There is substantial evidence that as intensity and duration of exposure to vibrating tools increase, the risk of developing HAVS increases. There also is evidence that an increase in symptom severity is associated with increased exposure. As intensity and duration of exposure are increased, the time from exposure onset and beginning of symptoms is shortened.

As described above, the relationship between vibration exposure and HAVS was evaluated favorably with regard to other epidemiological causality criteria, including consistency and coherency of available information and evidence describing the temporal sequence of exposure and outcome.

INTRODUCTION

The 20 epidemiologic studies discussed in this review were selected according to criteria that appear in the introduction of this document. In our review, we evaluated the studies according to criteria that enabled us to assess the research. These criteria, including adequate participation rate, definition of health outcome by both symptoms and medical exam criteria, blinding of investigators to exposure/outcome status, and independent/objective measure of exposure, also are described in detail in the Introduction.

In reviewing the studies, we gave greatest qualitative weight to those which fulfilled all four of the above research quality criteria. Table 5c-1 (all tables are presented at the end of the chapter) characterizes the 20 reviewed Hand-ArmVibration studies according to the four evaluation criteria. Full

summary descriptions of all the studies appear at the end of the chapter.

In addition to the four criteria we used to evaluate the studies, we determined whether studies demonstrated statistically significant associations between exposure attributes and health outcomes. We also examined whether the observed associations were likely to be caused or substantially influenced by major study flaws, including confounding and selection bias. Some of these limitations are shown in the descriptions of individual studies (Table 5c-2).

We then reviewed and summarized the studies with regard to standard criteria used by epidemiologists to evaluate the causal relationship between a health outcome and an exposure of interest. These criteria included strength of association, temporal relationship, consistency of association, coherence of association, and exposure-response relationships.

In this review, results of each of the studies examined, whether negative, positive, or equivocal, contributed to the pool of data used to make our decision regarding the strength of the causal relationship between HAVS and workplace risk factors. Greater or lesser confidence in the findings reflected the evaluation criteria described above.

Definition of HAV for HAVS

Hand-Arm Vibration is defined as the transfer of vibration from a tool to a worker's hand and arm. The amount of HAV is characterized by the acceleration level of the tool when grasped by the worker and in use. The vibration is typically measured on the handle of tool while in use to determine the acceleration levels transferred to the worker.

EVIDENCE FOR THE WORK-RELATEDNESS OF HAVS

The hazardous effects of occupational exposure to HAV have been discussed in hundreds of studies dating to the work of Loriga in 1911. The composite of vibration-induced signs and symptoms referred to as hand-arm vibration syndrome includes episodic numbness; tingling and blanching of the fingers, with pain in response to cold exposure; and reduction in grip strength and finger dexterity. These signs and symptoms are known to increase in severity as exposure to vibration increases in intensity and duration.

A review of pertinent epidemiologic studies of HAVS has been previously presented [NIOSH 1989]; therefore, Table 5c-2 includes only those studies completed after 1989. Except for a few longitudinal studies of chain sawyers in the United Kingdom,

Finland, and Japan, the literature comprises largely cross-sectional studies carried out within an industry. Cross-sectional studies are limited in their ability to ascertain temporal relationships between exposure and outcome. Because results are obtained at only one point in time, the cross-sectional study design also is subject to underassessment of the health outcome (particularly in groups with longer durations of employment and higher participant attrition).

The studies included in this review varied in design and quality of information. Sixteen were cross-sectional in design, and three were prospective cohort in design. One study was both cross-sectional and prospective, including 10 cross-sectional follow-ups over time and a cohort group [Koskimies et al. 1992]. Thirteen of the 20 studies reported assessing case status using physical exams, while other studies used only a questionnaire to determine outcomes. Of the studies in which the subjects underwent a physical exam, five performed a cold provocation test [Bovenzi et al. 1988; Bovenzi et al. 1995; Brubaker et al. 1983; Brubaker et al. 1987; McKenna et al. 1993], three performed a nail compression test [Mirbod et al. 1992(b); Nagata et al. 1993; Saito 1987], one performed a nerve conduction test [Virokannas 1995], one performed sensorineural physician testing [Bovenzi and Betta 1994], one performed a neurological exam [Shinev et al. 1992], one performed an Allan test [Nilsson et al. 1989] and one used physician judgement based on workers' complaints and history [Koskimies et al. 1992].

Twelve of the 20 studies conducted an exposure assessment of the tools subjects

were using; an additional study used exposure assessment information the authors had collected in a previous investigation. The remaining studies estimated exposures by self-report or job title.

The one study that met all four criteria and the four studies which met the three criteria are discussed in the following section. Detailed descriptions for all 20 investigations can be found at the end of the chapter.

Comments Related to Specific Studies of HAVS

The Bovenzi et al. [1995] cross-sectional investigation of forestry workers compared vibration white finger (VWF) in this group with shipyard worker referents. VWF was diagnosed by symptom report and cold provocation test; vibration exposures were estimated by questionnaire report on frequency of chain saw work and types of saws used, along with direct measurement of vibration produced by 27 antivibration and 3 non-antivibration saws. Daily exposure to saw vibration was estimated by linking the two assessments. The prevalence rates for VWF were 23.4% in forestry workers and 2.6% in shipyard referents (Odds ratio OR=11.8, 95% Confidence Interval (CI) 4.5–31.1). For workers using only antivibration saws, the OR was 6.2 (95% CI 2.3–17.1); for those using non-antivibration saws, the OR was 32.3 (95% CI 11.2–93). A dose-response was observed for VWF and lifetime vibration dose (OR = 34.3, 95% CI 11.9–99, for the highest category). Although participation rates were not stated for referents, the participation appeared to be 100% for forestry workers. Authors included 10 retired workers to lessen the problems

with selection out of the workforce. Results demonstrated that antivibration saw use was associated with a lower prevalence of VWF.

Koskimies et al. [1992] examined vibration syndrome in a group of forestry workers employed by the National Board of Forestry in Finland. All those employed in one parish participated in a series of 10 cross-sectional studies from 1972 to 1990. Results also were reported for a cohort of 57 individuals who remained in the study from 1972 to 1986. HAVS symptoms were assessed by questionnaire and physical exam criteria. Exposure to chain saw vibration was determined by measurement of front handle acceleration. Cross-sectional analysis results showed a monotonic decrease in prevalence of VWF from 40% in 1972 to 5% in 1990. In the cohort of 57, VWF increased from 30% in 1972 to 35% in 1975. VWF decreased monotonically to approximately 6% in 1986. Over the same time period, modifications of chain saws used by the workers resulted in a decrease in saw vibration acceleration from 14 m/s^2 to 2 m/s^2 . The authors attributed the reduction in VWF to saw changes, although exposures and outcomes were never linked for individual workers. Strengths of the study included observation of similar results from the series of cross-sectional analyses and full participation on the part of the 57 subjects. Limitations included failure to assess chain saw exposure measures at the individual level. The study demonstrated the potential for symptom improvement after exposure reduction.

In the Nilsson et al. [1989] cross-sectional study of male pulp mill machine manufacturing employees, VWF was examined in a group of 89 platers and 61

office workers. VWF was ascertained by physical exam and interview. For plasters, vibration exposure was assessed by measuring acceleration intensity on a sample of tools and linking results to subjective ratings of exposure time. Current and past exposures were estimated for both plasters and office workers (some office workers had experienced exposures in the past).

Prevalence for plasters with current exposure was 42%, in comparison to 2.3% for office workers with no exposures OR=85, 95% CI 15-486. When those exposed to vibration (plasters plus office workers with previous vibration exposure) were compared to unexposed office workers, prevalences were 40.0% and 2.3% respectively (OR=56; 95% CI 12-269). A dose-response was observed for VWF and years of exposure. The relationships between outcome and exposure, after adjustment for age, were strong. Representativeness of the referent group of office workers could not be determined.

Bovenzi et al. [1994] examined HAVS cross-sectionally in 570 quarry drillers and stone carvers, along with a referent group of polishers and machine operators who were not exposed to hand-transmitted vibration. HAVS was assessed by physician interview, and sensorineural symptoms were staged and graded. Exposure to vibrating tools was assessed by interview and linked to vibration measurements obtained from assessment of a sample of tools. Prevalences of HAVS were 30.2% in the exposed and 4.3% in the unexposed groups (OR=9.33, 95% CI 4.9–17.8). Symptoms of VWF increased with lifetime vibration dose (OR=10.2, 95% CI 4.8–21.6, for the highest category). Study strengths included detailed exposure assessment and modeling of relationships,

100% participation, and a very stable work population. Because of the work population stability, results were unlikely to be influenced by participant attrition.

The Bovenzi et al. [1988] cross-sectional investigation examined VWF in vibration-exposed stone drillers and stone cutters/chippers and a reference group of quarry and mill workers. VWF was assessed by questionnaire and physical exam. Exposure was assessed by measuring acceleration intensity on a sample of tools and linking it with self-reported exposure time. VWF prevalence rates were 35.5% in exposed and 8.3% in unexposed groups (OR=6.06, 95% CI 2.0–19.6; OR=4.26, 95% CI 1.8–10.4). A significant association was observed between vibration acceleration level and severity of VWF symptoms (0% and 18.4% in the lowest and highest categories, respectively).

Strength of Association

One of the studies examined met all four of the evaluation criteria [Bovenzi et al. 1995]. Four investigations met three of the criteria [Bovenzi et al. 1988; Bovenzi et al. 1994; Koskimies et al. 1992; and Nilsson et al. 1989]. The criterion that was not met (or not reported) by the four studies was blinding of the physician with regard to worker job status. However, most studies used objective measures for determining case status: cold provocation [Bovenzi et al. 1988; Bovenzi et al. 1995], sensorineural physician grading [Bovenzi et al. 1994], and the Allan test [Nilsson et al. 1989]. Use of objective measures lessens the likelihood that case status was influenced by knowledge of participants' exposures.

In the Bovenzi et al. [1988] cross-sectional investigation, vibration-exposed stone drillers and stone cutters/chippers showed a 6.06-fold (95% CI 2.0–19.6) increase in risk of VWF in comparison to unexposed quarry and mill workers. Similar results were observed in another study of stone workers conducted by Bovenzi et al. in 1994. Quarry drillers and stone carvers exposed to vibration showed an OR for VWF of 9.33 (95% CI 4.9–17.8) when compared to a reference group of polishers and machine operators. A dose-response relationship was observed for VWF and lifetime vibration dose, with an OR of 10.2 (95% CI 4.8–21.6) for the highest exposure category. A study of forestry workers [Bovenzi et al. 1995] demonstrated an OR of 11.8 (95% CI 4.5–31.1) for VWF when comparing forestry workers with exposure to chain saw vibration to an unexposed group of shipyard workers. A lower risk of VWF (OR=6.2, 95% CI 2.3–17.1) was observed for those using only antivibration saws. A dose-response between VWF and vibration exposure also was observed in this investigation, with an OR of 34.3 (95% CI 11.9–99) for the highest exposure category. Nilsson et al. [1989] observed very strong relationships between VWF and exposure to vibration in machine manufacturing platers. In comparison to office workers with no exposure, platers had an OR of 85 (95% CI 15, 486). Koskimies et al. [1992] examined a dynamic cohort of forestry workers at 10 intervals from 1972 to 1990 during which time saws were being modified in weight, vibration frequency, and vibration acceleration. Over the 18-year period, a monotonic decrease in VWF was observed in the 10 cross-sectional examinations, with an overall eight-fold reduction in prevalence. A subset of workers followed

from 1972 to 1986 showed a decrease in VWF from 30% to 6%. The reductions were attributed to modifications in chain saws during the same time period.

The remaining, less rigorous, studies showed varying relationships between HAVS and exposure. The majority of the studies demonstrated moderate to strong positive associations. Most compared exposed to unexposed groups with little or no detailed analysis by exposure level. Two investigations examined HAVS in exposed groups and found an increase in risk by years of employment, with ORs of 8.4 and 8.9 (95% CI 2.9–28.9) when comparing the highest and lowest categories [Mirbod et al. 1992b; Kivekas et al. 1994]. Another study that examined HAVS prevalence in power tool users found no association with duration of employment (with a participation rate of only 38%) [Musson et al. 1989]. For other investigations, exposed and unexposed groups were defined by job titles. ORs for these studies ranged from 3.2 to 40.6 (relative risk [RRs] from 3.2 to 16) [Brubaker et al. 1983; Dimberg and Oden 1991; Letz et al. 1992; McKenna et al. 1993; Mirbod et al. 1992a; Mirbod et al. 1994; Nagata et al. 1993]. Three studies demonstrated varying HAVS rates for exposed groups, but included no referents [Shinev et al. 1992; Starck et al. 1990; Virokannas et al. 1995].

Two investigations produced conflicting evidence related to the effects of chain saw modifications on HAVS in forestry workers. The Brubaker et al. [1987] study, observed a 28% increase in prevalence of VWF in a cohort of tree fellers over a 5-year period and claimed that saw modifications were ineffective. Saito [1987] found no new

HAVS symptom development over 6 years in a cohort of chain sawyers in reducing symptoms.

Comparing construction workers to office workers, one study demonstrated an OR of 0.5 (95% CI 0.1–11.8) for HAVS. This study met none of our four criteria [Miyashita et al. 1992].

In general, the studies in Table 5c-1 show strong evidence of a positive association between exposure to HAV and vascular symptoms of HAVS.

Temporality

The temporal relationship between HAV exposure and symptoms of HAVS is well established by studies which have determined the latency between exposure and symptom onset. Of 52 studies reviewed by NIOSH in 1989, 44 included some information about the latency period for the development of vascular HAVS symptoms following initial exposure. Latency ranged from 0.7 to 17 years, with a mean of 6.3 years. Unfortunately, because most of these studies were cross-sectional (i.e., latency was determined retrospectively) and because HAVS develop slowly, the possibility of recall bias is strong [Gemne 1993]. However, longitudinal studies provide support for the temporal nature of the association. Kivekas et al. [1994], in a 7-year follow-up of Finnish lumberjacks, found a cumulative incidence rate of 14.7%, compared to a cumulative incidence rate of only 2.3% among referents. The cumulative incidence rate of lumberjacks who had more than 25 years of exposure at the end of the follow-up period was 30.6%. Other studies of Finnish forestry workers also showed a

marked decrease in HAVS prevalence following the introduction of improved chain saws [Pyykko et al. 1986; Koskimies et al. 1992].

Consistency

The literature consistently shows that workers exposed to HAV develop HAVS at a substantially higher rate than workers not exposed to vibration. Although there is considerable variation in the occurrence of HAVS among different groups using similar types of vibrating tools, the lack of consistency probably is explained by methodological differences between studies (i.e., some researchers did not account for exposure variation over time in the summary estimate of exposure) or by differences in work methods, work processes, and work organization [Gemne et al. 1993]. Important also is the difference in the intensity and duration of exposure.

Coherence of Evidence

The mechanisms by which HAV produces neurological, vascular, and musculoskeletal damage are supported by some experimental evidence [Armstrong et al. 1987; Lundborg et al. 1990; Necking et al. 1992; Dehlin et al. 1994]. Neurological and circulatory disturbances probably occur independently and by unrelated mechanisms. Vibration may directly injure the peripheral nerves, nerve endings, and mechanoreceptors, producing symptoms of numbness, tingling, pain, and loss of sensitivity. Vibration also may have direct effects on the digital arteries. The innermost layer of cells in the blood vessel walls appears especially susceptible to mechanical injury by vibration. If these vessels are damaged, they may become less sensitive to the actions of

certain vasodilators that require an intact endothelium. Experiments involving lumberjacks exposed to chain saw vibration support this hypothesis [Gemne et al. 1993]. There also is evidence that the walls of the digital blood vessels are thickened in persons with HAVS [Takeuchi et al. 1986]. During cold exposure, vessels with these changes will become abnormally narrow and may close entirely [Gemne 1982]. Symptoms of numbness and tingling which characterize HAVS may be secondary to vascular constriction of the blood vessels, resulting in ischemia in the nerve-end organs.

Other evidence concerning the coherence of information regarding the association between vibration exposure and HAVS relates to background prevalence of similar disorders in the general population. One estimate placed the prevalence of Raynaud's phenomenon at 4.6% for females and 2.5% for males in the general population [Iwata et al. 1987]. Only 7 of the studies examined in this review found prevalence rates less than 20% among workers exposed to HAV. In the 1989 NIOSH review, only 9 of 52 cross-sectional studies reported a prevalence rate of less than 20% among workers exposed to HAV. This provides strong evidence that individuals working in vibration-exposed occupations are at much higher risk of these disorders than those in the general population.

Exposure-Response Relationship

Exposure-response relationships involving HAV have been postulated, including: (1) a relationship between the prevalence of HAVS and vibration acceleration (and cumulative exposure time), (2) a relationship between the dose and symptom severity,

and/or (3) a relationship between the dose and the latency of symptom onset.

Support for the first relationship is provided by a few longitudinal studies of workers exposed to HAV. In general, all show strong evidence that decreasing the acceleration level of a hand-held vibrating tool has a positive relationship with prevalence of HAVS. In a study of Finnish forestry workers using chain saws, Koskimies et al. [1992] found that the prevalence of HAVS symptoms declined from a peak of 40% to 5% after the introduction of light-weight, low-vibration chain saws with reduced acceleration from 14 to 2 m/s². Likewise, a study of similar workers in Japan found that the prevalence of vascular symptoms among chain saw operators who began their jobs before the introduction of various engineering and administrative controls peaked at 63%. (Vibration acceleration levels for chain saws used during this period ranged from 111 to 304 m/s².) In contrast, the peak prevalence for chain saw operators who began working after the introduction of antivibration chain saws (acceleration level: 10-33 m/s²) and exposure duration limits (2 hrs/day) was only 2% [Futatsuka and Veno 1985, 1986].

NIOSH authors ranked 23 cross-sectional studies that measured HAV acceleration levels and estimated a prevalence rate for vascular symptoms [NIOSH 1989]. To test whether a linear relationship existed between the HAV level and the prevalence of vascular symptoms, a correlation coefficient was calculated. The correlation analysis found a statistically significant linear relationship between HAV acceleration level and prevalence of vascular symptoms ($R=0.67$, $p < 0.01$), indicating that prevalence of vascular symptoms tends

to increase as the HAV acceleration level increases. However, the absorption of vibration energy by the hand is influenced by the vibration intensity, as well as by frequency, transmission direction, grip and feed forces, hand-arm postures, and anthropometric factors [Gemne et al. 1993].

Several studies reviewed for the current document found relationships between prevalence of HAVS and duration of vibration-exposed work [Bovenzi et al. 1994; Bovenzi et al. 1995; Letz et al. 1992; Nilsson et al. 1989]. One cross-sectional study with a very poor response rate found no association with duration of exposure [Musson et al. 1989].

Justification for a relationship between dose and HAVS prevalence and symptom severity is provided by Bovenzi et al. [1988] and Mirbod et al. [1992b]. In a study of stone-cutters using rock drills and chisel hammers, Bovenzi found that HAVS prevalence increased linearly with the total number of working hours, from about 18% for persons with 6,000 hrs of exposure, to more than 50% among persons with more than 26,000 hrs of exposure. Likewise, in a study of 447 workers using chain saws, Mirbod et al. [1992b] found that the prevalence of HAVS increased from 2.5% among workers with less than 14 years of exposure to 11.7% among workers with 20–24 years exposure, to 20.9% among workers exposed 30 years or more. Both studies found a statistically significant correlation between the severity of symptoms (graded according to the Taylor-Pelmear scale) and a dose measure based on total exposure time.

Support for a relationship between dose and latency of symptom onset is provided by British studies conducted in the 1970s among various occupational groups, including chain sawyers, grinders, chiselers and swagers [Gemne et al. 1993]. Exposure to 10-25 m/s² chainsaw vibration correlated with a latency of about 3 years. Pedestal grinders using machines with zirconium wheels were exposed to vibration levels of 50 m/s² and demonstrated a mean latency of 1.8 years, whereas grinders who used softer wheels with accelerations of 10-20 m/s² had a mean latency of 14 years. Exposure to 70 m/s² vibration during swaging correlated with a mean latency of about 7 months, although some swagers developed symptoms in as few as 6 weeks.

Confounding and HAVS

Age and metabolic disease are the primary potential confounders for HAVS.

It is important that epidemiologic studies examine non-occupational factors, and control for them. Most of the studies were able to address “age” by stratification in their analyses, or through use of multiple logistic regression. [Bovenzi and Betta 1994; Bovenzi et al. 1995; Brubaker 1983, 1987; Kivekas et al. 1994; Letz et al. 1992; McKenna et al. 1993; Mirbod et al. [1994]. Several authors controlled for metabolic disease [Bovenzi and Betta 1994; Bovenzi et al. 1995; Letz et al. 1992; McKenna et al. 1993]. This is important because of the effects that some disorders have on peripheral circulation which may have symptoms similar to HAVS.

Nonoccupational Raynaud's phenomena - a rare disorder which mimics HAVS has been known to occur in individuals with metabolic disorders, peripheral neuropathy, alcohol-related illness, as well as other conditions.

In reviewing the methods and results of these studies, taking into account substantially elevated ORs and evidence of dose-response relationships, it appears that potential confounders do not account for the consistent relationships seen.

Review of the 20 studies, leads us to the conclusion that there is substantial evidence that as intensity and duration of exposure to vibrating tools increase, the risk of

developing HAVS increases. Most of the studies showed a positive association between high level exposure to hand-arm vibration and vascular symptoms of hand-arm vibration syndrome. For many of the studies there is a strong association between HAVS and exposure to vibrating tools in the workplace. The temporal relationships and consistency between exposure and symptoms of HAVS are well established in these studies. The mechanisms by which HAV produces neurological, vascular, and musculoskeletal damage are supported by some experimental evidence. Many of the studies showed an exposure-response relationship between dose of HAV and the HAVS prevalence and symptom severity.

Table 5c-1. Epidemiologic criteria used to examine studies of hand/wrist and hand/arm MSDs associated with vibration

Study (first author and year)	Risk indicator (OR, PRR, IR or p-value) [*] ,†	Participation rate ≥70%	Physical examination or cold provocation	Investigator blinded to case and/or exposure status	Basis for assessing hand/wrist or hand/arm exposure to vibration
Met all four criteria:					
Bovenzi 1995	6.2–32.3 [†]	Yes	Yes	Yes	Observation or measurements
Met at least one criteria:					
Bovenzi 1988	6.06 [†]	NR	Yes	NR [‡]	Observation or measurements
Bovenzi 1994	9.33 [†]	Yes	Yes/No	No	Observation or measurements
Brubaker 1983	NR	Yes	Yes	NR	Job titles or self-reports
Brubaker 1987	NR	No	Yes	NR	Observation or measurements
Dimberg 1991	NR	Yes	No	NR	Job titles or self-reports
Kivekas 1994	3.4–6.5 [†]	Yes	No	No	Job titles or self-reports
Koskimies 1992	NR	Yes	Yes	NR	Observation or measurements
Letz 1992	5.0–40.6	Yes	No	No	Job titles or self-reports – previous study results used
McKenna 1993	24.0 [†]	NR	Yes	No	Job titles or self-reports
Mirbod 1992b	NR	NR	Yes	No	Observation or measurements
Mirbod 1992a, 1994	3.77 [†]	NR	NR	NR	Observation or measurements
Musson 1989	NR	No	No	No	Observation or measurements
Nagata 1993	7.1 [†]	NR	Yes	No	Job titles or self-reports
Nilsson 1989	14–85	Yes	Yes	NR	Observation or measurements
Saito 1987	NR	No	Yes	NR	Job titles or self-reports
Shinev 1992	NR	NR	Yes	NR	Observation or measurements
Starck 1990	NR	NR	No	No	Observation or measurements
Virokannas 1995	NR	NR	Yes	NR	Observation or measurements
Met none of the criteria:					
Miyashita 1992	0.5	NR	No	No	Job titles or self-reports

* Some risk indicators are based on a combination of risk factors—not on vibration alone (i.e., vibration plus force, posture, or repetition). Odds ratio (OR), prevalence rate ratio (PRR), or incidence ratio (IR).

† Indicates statistical significance. If combined with NR, a significant association was reported without a numerical value.

‡ Not reported.

Figure 5c-1. Risk Indicator for Hand/Arm Vibration Syndrome (Odds Ratios and Confidence Intervals)

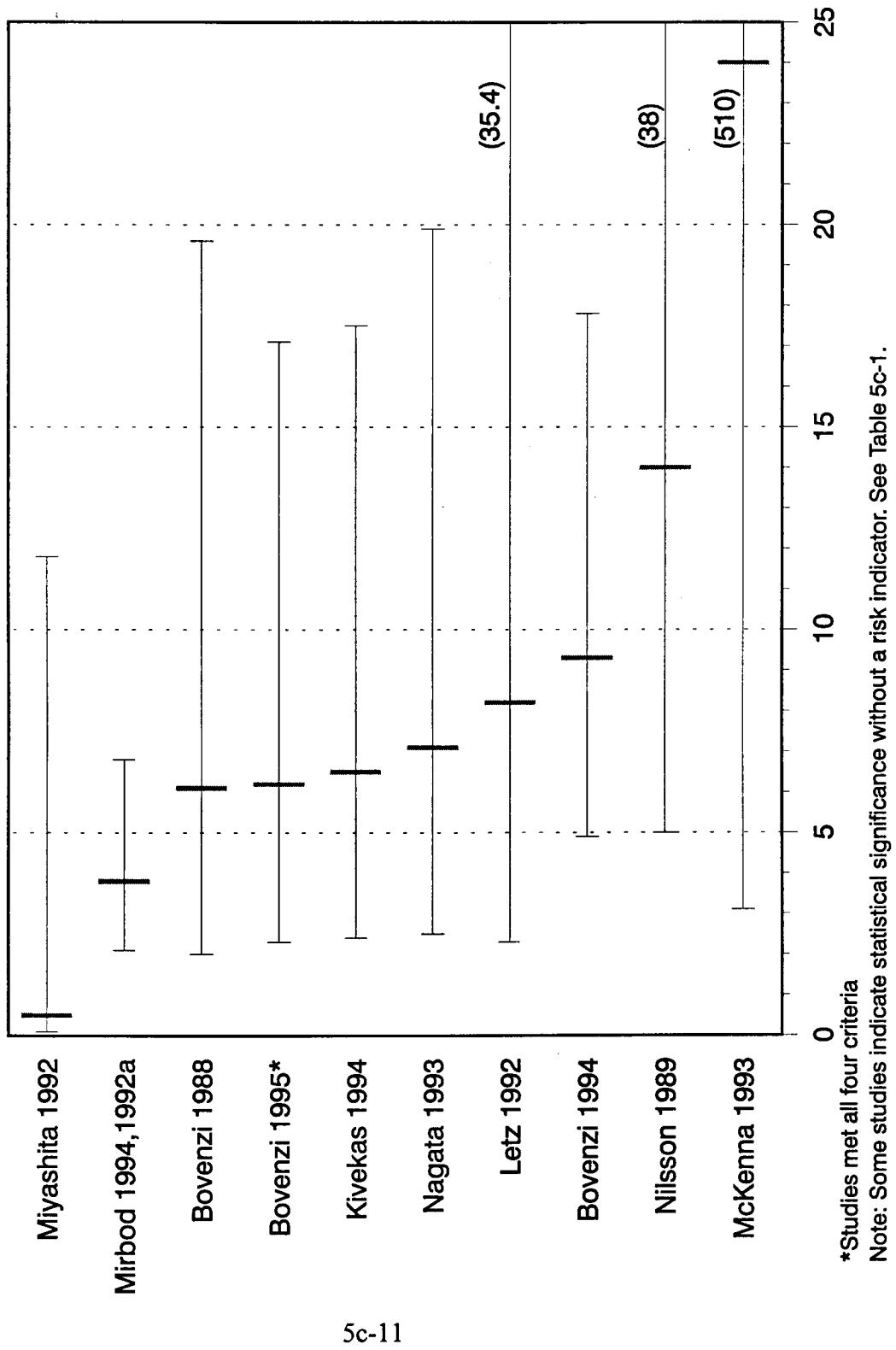


Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Bovenzi et al. 1988	Cross-sectional	Vibration-exposed stone drillers ($n = 32$) and stone cutters/chippers ($n = 44$); quarry and mill workers not exposed to vibration (control group, $n = 60$).	Outcome: Assessed by physical examination and questionnaire. VWF symptoms staged using the Taylor-Pelmeir scale. Exposure: Vibration exposure assessed by measuring the acceleration intensity on a sample of tools, together with subjective ratings of exposure time.	35.5%	8.3%	6.06	2.01-19.6	Participation rate: Participation rate cannot be determined from data in the study. Significant association between vibration acceleration level and severity of VWF symptoms. Mean latency period to symptom onset = 12.3 yr.

5c-12

(Continued)

Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence			Comments
				Exposed workers	Referent group	RR, OR, or PRR 95% CI	
Bovenzi et al. 1994	Cross-sectional	Case group: Stone workers employed in nine districts in Northern and Central Italy; 145 quarry drillers and 425 stone carvers exposed to vibration. Referent group: polishers and machine operators ($n = 258$) who performed manual activity only not exposed to hand-transmitted vibration.	Outcome: HAVs assessed by physician-administered interview; sensineurial symptoms staged according to Brammer (1992). Graded according to the Stockholm scale (Gemne, 1987). Exposure: To vibrating tools assessed by interview. Vibration measured in a sample of tools used.	30.2%	4.3%	9.33 4.9-17.8	Participation rate: 100% "All the active stone workers participated in the study, so self-selection was not a source of bias." Physician administered the questionnaires containing work history and examinations, so unlikely to be blinded to case status. Adjusted for age, smoking, alcohol consumption, and upper limb injuries. Leisure activities, systemic diseases included in questionnaire. Univariate analysis showed no association between systemic diseases and vibration so was not criteria for exclusion. Univariate analysis showed no association between systemic diseases and vibration so was not criteria for exclusion. Dose-response for CTS and lifetime vibration exposure not significant.

Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence					
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	Comments	
Bovenzi et al. 1995	Cross-sectional	222 active forestry workers and 10 retired forestry workers with > 400 hr of sawing compared with 195 randomly chosen shipyard workers never exposed to hand vibration. Controls excluded for cardiovascular and metabolic disease.	Outcome: (1) History of episodes of cold provoked well-demarcated blanching in one or more fingers and (2) Occurrence after employment and exposure to hand vibration and vibration white finger (VWF) attacks in last 2 years and (3) Abnormal digital arterial response to cold provocation. Clinically, VWF graded using Stockholm scale. Exposure: Vibration measured on front and rear of 27 antivibration (AV) chain saws used in the forest; for previous exposure assessment, 3 non-AV chain saws were measured. Vibration measurements were made in the field during cross-cutting operations by skilled workers according to ISO 7,505.	All Forestry workers: 23.4% Workers using only AV chain saws: 13.4%	Shipyard workers: 2.6% Workers using chain saws without vibration isolation systems: 51.7%	(adjusted OR's)	11.8 6.2	4.5-31.1 2.3-17.1	Participation rate: 95% vibrating tool users, not reported for control. Analysis controlled for age, smoking, drinking habits. Physicians blinded to case status—since cold provocation test was used, it was not an issue. Smoking, alcohol, metabolic, cardiovascular, neurologic, previous musculoskeletal injuries, use of medicines included in questionnaire and accounted for in logistic regression model.

5c-14

(Continued)

Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Brubaker et al. 1983	Cross-sectional	146 tree fellers in 7 camps employed for ≥ 1 year compared to 142 workers not exposed to vibration matched for location.	Outcome: VWF symptoms staged using Taylor-Pelmeer scale. Ischemic water bath testing for VWF completed on all subjects. Exposure was based on questionnaire data.	With symptoms: 51% Stage 3: 22% Excluding other vibration exposure and medical history: 54%	With symptoms: 5% Stage 3: 2% Excluding other vibration exposure and medical history: 54%	— —	— —	Participation rate: 100%. Smoking, no significant differences. Age was significantly different between cases and controls. Height and weight not significantly different. Mean latency period between work and symptoms 8.6 years. Records of duration of exposure.

5c-15

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Brubaker et al. 1987	Cohort: 5-year follow-up of exposed group.	Fellers at Canadian lumber camps (n = 71) who had been interviewed and tested in 1979 to 1980 then again in 1984 to 1985.	Outcome: Defined as HAVs symptoms, assessed by questionnaire and digit systolic blood pressure. VWF symptoms staged using Taylor-Pelmeir scale. Ischemic water bath testing for VWF completed on all subjects.	Raynaud's symptoms: 53% (1984 to 1985) Tingling, numbness: 56% (1984 to 1985)	Raynaud's symptoms: 51% (1979 to 1980) Tingling, numbness: 65% (1979 to 1980)	—	—	Participation rate: 53%. Original group (1979 to 1980) included 146 fellers. 16 fellers excluded because of potential confounders. Author concluded antivibration saws not effective at preventing HAVs. 15% of fellers reported new symptoms of VWF over 5-year period.

5c-16

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Dimberg and Ogen 1991	Cross-sectional	2,814 Aircraft engine workers.	Outcome: Exposure to vibrating hand-tools assessed by questionnaire. White fingers as a spasm in blood vessels occurring in one or more fingers in connection with cooling leading to reversible pallor followed by redness.	23% (polishers/grinders)	—	Multivariate analysis showed increased symptoms with increasing age, work with vibrating hand tools and weight loss	—	Participation rate: 96% questionnaire.
		68 Sheet metal workers.		19% (sheet metal workers)				Vibrating tool use significantly correlated with HAVs symptom prevalence.
		26 Polishers/grinders.						Analysis was stratified by gender, age, and employment category.
		20 Cleaners.						
		40 Forklift-truck drivers.						
		46 Engine testers.						
		146 Fitters.						
		49 Storemen	Exposure: Vibration assessed by questionnaire:					
		38 Electric welders.	working in present job, leisure time in present job, leisure activities.					
		No control group used.						

5c-17

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Kivekas et al. 1994	Cohort with 7-year follow-up (1978 to 1985)	213 lumberjacks and 140 referents.	Outcome: HAVs assessed by questionnaire, clinical examination, and radiographs. Exposure: Not measured. Exposure history determined via questionnaire.	Prevalence (HAVs): 1978: 16.9% 1985: 24.9%	Prevalence (HAVs): 1978: 5.0% 1985: 5.7%	For 1978: OR = 3.4	1.7-6.9	Participation rate: 76% among exposed workers, 78% among control.
				Cumulative incidence HAVs (7 years): 14.7%	Cumulative incidence HAVs (7 years): 2.3%	For 1985: OR = 4.4	2.3-8.1	Follow-up group included 76% of lumberjacks and 78% of referents from original group.
				OR = 6.5	2.4-17.5	Adjusted for age.		X-ray films read by radiologists blinded to case status
								After adjusting for age, no difference in lumberjacks with <15-years exposure and referents, but risk increased with increasing duration of exposure. For those exposed RR = 8.9 (2.9-28.9).
								No X-ray differences in prevalence of detectable transluencies or osteoarthritic changes in wrists or hands.

Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Koskinies et al. 1992	Cohort (18-year follow-up)	Finnish forest workers (n = 118-124).	Outcome: HAVs assessed by questionnaire and physical examination. Exposure: Vibration acceleration of the front handle of chain saws analyzed.	Prevalence of HAVs among forestry workers in 1990: 5% 1972: 40%	Prevalence of HAVs among forestry workers in 1990: —	—	—	Participation rate: 100% of those who had a yearly physical exam. Decrease in prevalence attributed to reduction in weight of saws, increase in vibration frequency, and reduction in vibration acceleration (from 14 to 2 m/s ²).

5c-19

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments	
				Exposed workers	Referent group	RR, OR, or PRR	95% CI		
Letz et al. 1992	Cross-sectional	Shipyard workers with full-time vibration exposure ($n = 103$), part-time vibration exposure ($n = 115$), and no vibration exposure ($n = 53$, comparison group).	Outcome: HAVs assessed by self-administered questionnaire; graded according to the Stockholm scale. Vibration measurements from 51 pneumatic tools made in 3 studies. Extreme variability precluded direct comparison of tools. Number of hours per week and years using tools asked.	Vascular symptoms among full-time vibration-exposed workers: 70.9%; Vascular symptoms among part-time vibration-exposed workers: 33%	Vascular symptoms: 5.7% Sensori-neural symptoms: 17% Sensori-neural symptoms among part-time vibration-exposed workers: 50.4%	Part-time vibration-exposed workers vs. controls: OR = 8.23 Full-time vibration-exposed workers vs. controls: OR = 40.6 Part-time vibration-exposed workers vs. controls: OR = 5.0 Full-time vibration-exposed workers vs. controls: OR = 24.7 Median latency for appearance of symptoms of white finger tool/use and 8,200 hrs for numbness.	2.3-35.4 11-177 2.1-12.1 9.5-67	Participation rate: 79%. Participants randomly selected within departments. Significant exposure-response relationship found after adjustment for smoking, not age or race. Average latency to symptom onset < 5 years. Alcohol consumption, past medical conditions considered in analysis. Exposure-response relationship found regarding self-reported cumulative exposure to vibratory tools, sensorineurial stages, and corresponding vascular classifications but no further increases in workers with > 17,000 hrs of exposure.	Participants not blinded to purpose of questionnaire may have been over-reporting.

Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
McKenna et al. 1993	Cross-sectional	46 pairs of riveters and matched control subjects (machine operators who had never used vibrating tools).	Outcome: Defined as cold-induced digital vasospasm. Exposure: To specific tools assessed via questionnaire.	35%	2%	24	3.1-510	Participation rate: Not reported. Matched on age and smoking habits. Only males studied. Excluded those with injury to neck, trunk, upper limbs. 44% of riveters had <2.5 years of vibration exposure. Did not of blind examiners because they tested the most symptomatic finger. No differences in resting finger systolic pressure, vibration perception, or finger temperature between cases and controls. 17% of riveters reported symptoms of VWF.

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Mirbold et al. 1992b	Cross-sectional	Forestry workers (n = 447)	Outcome: HAVs assessed by interview and physical examination. Symptoms graded using the Stockholm scale.	9.6% overall	—	—	—	Participation rate: Not reported.
		No control group used.		20.9% among workers with 30 or more years experience				HAVs symptom severity positively correlated with exposure duration.
			Frequency-weighted vibration-acceleration measurements made on the hands of chain saw operators during different job processes.	2.5% among workers < 14 years				Chain saw vibration levels ranged from 2.7 to 5.1 m/s ² . Low prevalence attributed to recent improvements in working conditions.
				11.7% 20 to 24 years				

5c-22

(Continued)

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Mirbod et al. 1994; Mirbod et al. 1992a	Cross-sectional	(A) 164 male dental technicians, (B) 54 male orthopedists, (C) 256 male aircraft technicians, (D) 79 male laborers, (E) 27 male grinders, (F) 46 female sewing-machine operators, (G) 23 male tea-harvesting-machine operators, (H) 272 male chain-saw operators; compared with 1,027 males and 1,301 females not exposed to vibration.	Outcome: HAVs assessed by questionnaire, interviews, field visits, or annual health examinations. Exposure: To vibrating tools assessed by questionnaire and interviews. Hand-transmitted vibration measured among a sample of workers using representative tools in actual work activities.	(See first column for job categories)	Males: 2.7% Females: 3.4%	H vs. unexposed Males: 3.77	2.1-6.8	Participation restricted to workers age 30 to 59 years. Subjects stratified by age in analysis.
				A: 4.8% B: 3.7% C: 2.3% D: 2.5% E: 3.7% F: 4.3% G: 0.0% H: 9.6%				Hand-transmitted vibration levels in groups A to G ranged from 1.1 to 2.5 m/s ² . Hand-transmitted vibration levels in group H ranged from 2.7 to 5.1 m/s ² .

Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Miyashita et al. 1992	Cross-sectional	355 Male construction workers (machine operators) compared with 44 male office workers. (A) 184 power shovel operators. (B) 127 bulldozer operators. (C) 44 forklift operators.	Outcome: HAVs assessed by self-administered questionnaire. Exposure: Status assumed from job title (no objective measurements performed). Vibration due to construction-machinery operation.	1.1%	2.3%	0.5	0.1-11.8	Participation rate: Not reported. Participation restricted to male workers age 30 to 49.

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Mussom et al. 1989	Cross-sectional	Impact power-tool users in The Netherlands (n = 169).	Outcome: HAVs based on symptoms, assessed via postal questionnaire.	17%	—	—	—	Participation rate: 38% questionnaire. Adjusted for age. Exposure duration not related to HAV symptoms.

Table 5c–2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Nagata et al. 1993	Cross-sectional	179 chain-saw workers and 205 local inhabitants who had never used vibrating tools (control group).	Outcome: HA/s assessed by dermatological tests and physical examination. Exposure: Vibration not measured directly; exposure duration expressed as years since commencement of occupation.	>20-years exposure: 16%	2.9%	7.1 for >20-years vibration exposure	2.5-19.9	Participation rate: Not reported. Adjusted for age. Examiners not blinded to exposure status.

5c-26

(Continued)

Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence			
				Exposed workers	Referent group	RR, OR, or PRR	95% CI
Nilsson et al. 1989	Cross-sectional	Platers (n = 89) and office workers (n = 61) divided into 4 groups according to current and past vibration exposure.	Outcome: Assessed by physical examination and interview. VWF symptoms staged using the Taylor-Pelmeir scale. Exposure: Vibration exposure assessed by measuring the acceleration intensity on a sample of tools, subjective ratings, and objective measures of exposure time.	Platers with current exposure: 42%. Platers with current and former exposure. Platers and office workers with current or former exposure.	Office workers with no exposure: 2% Office workers with no vibration exposure and former exposure: 14	85 5-38	15-486 Mean latency to symptom onset = 9.8 years.
							Participation rate: 79% among platers, not reported among control. Controlled for age. Vibration acceleration levels = 5.5 m/s ² (grinders), 10.3 m/s ² (hammers), 1.5 m/s ² (die grinders). Odds ratio increased by 11% for each year of exposure. No correlation between the Taylor-Pelmeir stage and years of exposure.
							12-269

Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Saito 1987	Cohort: 6-year follow-up prospective	Chain sawers without HAV symptoms in 1978 ($n = 155$) followed up in 1983.	Outcome: Assessed by symptoms, skin temperature, vibration threshold, nail compression, pain sense, and cold provocation. Exposure: Chain saw operating time determined by questionnaire.	0% in 1983	0% in 1978	—	—	Participation: Follow-up of cohort. Improvements in chain saw design, age restrictions, and a decrease in weekly operating time credited for preventing HAV. Recovery rates of skin temperature after 10-min provocation test significantly better in 1982 and 1983 compared to 1978. Vibratory sense thresholds at 5th minute after cold provocation significantly better in 1980, 1982, and 1983 compared with 1978. Age significance correlated to recovery rates from 1978 to 1983.

Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Shine et al. 1992	Cross-sectional	77 male fettlers; 59 male molders; 85 male polishers. No control group used.	Outcome: HAV assessed by neurological examination. Exposure: Vibration characteristics of chipping and caulking hammers, air tampers, and polishing machines measured.	22.1% (fettlers) 6.8% (molders) 25% (polishers)	— — —	— — —	— — —	Participation rate: Not reported. Percussive vibration had greater effect on muscle and bone pathology than constant high-frequency vibration.

Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Starck et al. 1990	Cross-sectional	Forest workers ($n = 200$), pedestal grinders ($n = 12$), shipyard workers ($n = 171$), stone workers ($n = 16$), and platers ($n = 5$). No control group used.	Outcome: HAV based on symptoms, assessed via questionnaire. Exposure: Vibration measurements taken on a sample of tools during normal operation at the workplace.	40% (forest workers using 1st generation chain saw)	—	—	—	Participation rate: Not reported. No demographic data about study participants provided. Poor correlation between vibration exposure and HAV when tools were highly impulsive.

Table 5c-2. Epidemiologic studies evaluating work-related hand-arm vibration syndrome

Study	Study design	Study population	Outcome and exposure	MSD prevalence				Comments
				Exposed workers	Referent group	RR, OR, or PRR	95% CI	
Virokannas 1995	Cross-sectional	Railway workers ($n = 31$) and lumberjacks ($n = 32$) exposed to HAV. No controls used. Article evaluates the vibration perception threshold among exposed workers and tries to determine a dose-response relationship between exposure to HAV and the VPTs.	Outcome: "History of attack" of white finger reported by subjects. VPT and electromyography used as indicators of sensory nerve damage (outcome measure). Exposure: To vibrating tools assessed by interview. (No measurements performed). Groups asked about exposure time with self-estimated annual use of vibrating tools and vehicles (hr) and number of years of exposure to vibration. Mean (SD) duration of exposure to vibration was 8,050 (3,500) among railway workers and 21,250 (10, 950) hrs among lumberjacks.	Railway workers: 45% VWF	—	—	—	Participation rate: Not reported.